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NEW PATENT APPLICATION

METHOD AND APPARATUS FOR HIGH SPEED  
ATOMIC LAYER DEPOSITION

Inventor: Colin John Dickinson

METHOD AND APPARATUS FOR HIGH SPEED  
ATOMIC LAYER DEPOSITION

Background of the Invention

[0001] This invention is directed to atomic layer deposition. More particularly this invention provides an apparatus and process in which precursor gases including the species used to form monatomic layers can be quickly alternated so as to allow the atomic layer deposition process to be conducted with fast cycle time.

[0002] Atomic layer deposition is a method of depositing very thin films onto a surface. Individual precursor gases are pulsed onto the surface, typically a wafer, in a sequential manner without mixing the precursors in the gas phase. Each precursor gas reacts with the surface to form an atomic layer in a way such that only one layer at a time can be deposited onto the surface.

[0003] In order to avoid clogging and reaction of the precursor gases in areas other than the desired surface, inert gases such as argon and nitrogen are used as purge gases between application of different precursor gases. For example,  $\text{Si}_2\text{Cl}_6$  and  $\text{NH}_3$ ,  $\text{TiCl}_4$  and  $\text{NH}_3$ ,  $\text{Si}_2\text{Cl}_6$  and activated  $\text{NH}_3$  are commonly used precursors.

[0004] Unfortunately, interruption of flow of a precursor gas in order to allow introduction of another precursor gas can result in condensation related problems especially when using unstable precursors.

[0005] Accordingly, there is a need for an atomic layer deposition arrangement and process which reduces condensation, avoids clogging and reaction of the precursor gases in areas other than the desired surface, minimizes gas turbulence and provides fast cycle time.

Summary of the Invention

[0006] It is an object of the invention to provide an atomic layer deposition arrangement and process which avoids undesirable condensation of precursor gases.

[0007] Another object of the invention is to provide an atomic layer deposition arrangement and process which allows fast cycle times for precursor gases.

[0008] A further object of the invention is to provide an atomic layer deposition arrangement and process which provides steady flow of precursor gases.

[0009] An additional object of the invention is to provide an atomic layer deposition arrangement and process which provides for reduced use of a purge gas between pulses of precursor gases.

[00010] Another object of the invention is to provide an atomic layer deposition process and apparatus which provides fast evacuation of precursor gases from the process chamber.

[00011] These and other objects of the invention are provided by an atomic layer deposition arrangement comprising a process reactor chamber including an inlet for receiving precursor gases and at least one outlet coupled through an outlet line to an exhaust pump, a first precursor gas valve which receives a first precursor gas and second precursor gas valve which receives a second precursor gas. The first precursor gas valve and second precursor gas valve are coupled to the inlet of the process reactor chamber. A first bypass conduit coupled to the first precursor valve and a second bypass conduit coupled to the second precursor valve allows steady flow of the precursor gases in between delivery to the process

reactor chamber. The first bypass conduit and second bypass conduit are isolated from the outlet line. The outlet line coupled to the exhaust pump allows fast evacuation of the process reactor chamber.

[00012] The invention also provides a method for delivering precursor gas to an atomic layer deposition chamber comprising introducing a substrate into a process reactor chamber having a chamber inlet and a chamber outlet, reducing pressure in the chamber, flowing a first precursor gas to an inlet of a bypass position of a first gas valve, the first gas valve including a chamber delivery position coupled to the chamber inlet, switching the first gas valve to the chamber delivery position to convey the first precursor gas from the gas valve to the chamber inlet, switching the first gas valve to the inlet of the bypass position of the first gas valve, reducing pressure in the chamber, flowing a second precursor gas to the inlet of a bypass position of a second gas valve, the second gas valve including a chamber delivery position coupled to the chamber inlet, switching the second gas valve to a chamber delivery position to convey the second precursor gas from the second gas valve to the chamber inlet, and switching the second gas valve to the inlet of the bypass position of the second gas valve wherein the second precursor gas is conveyed to the chamber inlet without previously purging the chamber with a purge gas.

#### Brief Description of the Drawings

[00013] Fig. 1 is a schematic illustration of an atomic layer deposition arrangement in accordance with the invention;

[00014] Fig. 2 is a schematic illustration of an atomic layer deposition arrangement including two way valves in accordance with the invention,

[00015] Fig. 3 is a partial cross-section view of a substrate receiving mechanism within the process chamber reactor;

Fig. 4 is a schematic illustration of an atomic layer deposition arrangement including a purge gas system in accordance with the invention; and

Fig. 5 is a schematic illustration of an atomic layer deposition arrangement including two way valves to meter the precursor gases in accordance with the invention.

#### Detailed Description of The Preferred Embodiments

[00016] A schematic illustration of an atomic layer deposition arrangement in accordance with the invention is shown in Figure 1.

[00017] The atomic layer deposition system includes a process reactor chamber 10 including an inlet 12 for receiving precursor gases. A process reactor chamber outlet 14 is coupled through an outlet line 16 to an exhaust pump 18. The exhaust pump may be any suitably sized vacuum pump, such as the EPX 180L Dry Pump available from BOC Edwards. A first precursor gas valve 20 receives a first precursor gas A and a second precursor valve 22 receives a second precursor gas B. A first bypass conduit 24 is coupled to first precursor valve 20 and a second bypass conduit 26 is coupled to second precursor valve 22. As can be seen from Fig. 1, first bypass conduit 24 and second bypass conduit 26 are isolated from outlet line 16.

[00018] In an alternate embodiment, two sets of two way valves 45 can be used instead of a three way valve as shown in Figure 2.

[00019] In a typical atomic layer deposition process, a substrate is introduced into the process reactor chamber 10 through an opening, which is selectively closed through gate valve 30. The substrate may be for example, a processed semiconductor wafer, an unprocessed semiconductor wafer or a substrate intended for a flat panel display and/or any other type of substrate. A vacuum hold down is applied to the platen 32 by opening vacuum valve 34. The exhaust pump 18 is in flow communication with the chamber 10. Vacuum valves 34, 35 are arranged in direct communication with the chamber 10 and a vacuum hold down system 40. The vacuum hold down system 40 is configured to hold the substrate onto platen 32 during movement of the platen 32. Vacuum valve 42 may be in flow communication with the chamber 10 through the sub-chamber 44. A plurality of vacuum gauges 36, 38 may be provided to monitor the rate of evacuation of the chamber 10 through the vacuum valves 34, 35 and 42.

[00020] A check valve 46 may be associated with the gas flow path downstream from exhaust valve 48 to prevent back flow of gas while the exhaust valve 48 is open in the event the chamber 10 is under pressurized. The vacuum pump 18 is connected to a vent 50.

[00021] A more detailed view of the platen 32 is shown in Figure 3. The platen 32 is attached to a movement mechanism 52 which may be a linear actuator, a hydraulic piston, a pneumatic piston, or any other mechanism suitable for linear motion to the platen 32. The platen 32 has at least one through hole 100 formed therein. The platen 32 also has a first hollow shaft portion 102 and a second hollow shaft portion 104 in flow communication with the through hole 100 in the platen. A port member 106 is inserted into vacuum outlet 40, which is in flow communication with the hollow shaft portion 102. The other end of the port member 106 is in flow communication with the vacuum pump 18, shown in Fig. 1. The

structure 122 forming a flow path placing the through hole 100 in flow communication with the vacuum pump 18 forms a vacuum hold down that secures the object to the surface of the platen 32. A plurality of raised portions 124 assist in distributing vacuum force to the surface of the platen and thereby aid in securing an object to the platen 32.

[00022] The end of the hollow shaft portion 102 opposite the platen 32 is attached to a movement mechanism 52 which may be a linear actuator, a hydraulic piston, a pneumatic piston, or any other mechanism suitable for providing linear motion to the platen 32.

[00023] The movement mechanism 52 is arranged within a support member 110 affixed to the sub-chamber 44. The sub-chamber 44 may be fastened to the chamber 10 of Fig. 1 via one or more through holes 114 (only one of which is shown). This arrangement allows the platen 32 to be raised and lowered in relation to the sub-chamber 44 and the interior of the chamber 10. A steel bellows 116 is also contained within the sub-chamber 44 to cooperate with a radially extending flange portion 118 on the hollow shaft portion 102 to seal the sub-chamber 44 around the hollow shaft portion 104.

[00024] The sub-chamber 44 includes an outlet 14 (e.g., exhaust port) that provides flow communication between the interior of the chamber 10 of Fig. 1 and vacuum pump 18. The outlet 14 and outlet line 16 define an exhaust flow path that may be connected to both the vacuum pump 18 and the exhaust valve 48, shown in Fig. 1, to provide vacuum flow in the exhaust flow path.

[00025] The platen 32 is arranged above the outlet 14 and is movable in the interior of the chamber 10 so as to adjust conductance of the exhaust flow from the interior of the chamber 10 to the exhaust flow path via the outlet 14. For example, the platen 32 can be

raised and lowered to vary the distance H between a lower surface 126 of the platen and the upper surface 128 of the sub-chamber 44. Varying the distance H controls the rate at which gas is withdrawn from the chamber 10 during placement of the chamber into vacuum condition and varies the conductance between the platen 32 and the sub-chamber 44 through the outlet 14. This object receiving mechanism 130 is configured to increase throttling of gas being withdrawn when the object receiving mechanism 130 is in a lowered position and to decrease the throttling when the object receiving mechanism 130 is in a raised position. This may prevent damage to the object 28 during the gas evacuation process. In addition, by raising the object receiving mechanism 130, the conductance is increased and by lowering the object receiving mechanism 130, the conductance is decreased.

[00026] By monitoring the vacuum gauges 36, 38, shown in Fig. 1, it is possible to control the movement mechanism 52 to vary the distance H and thereby adjust the flow rate of withdrawn gas. Alternatively, without relying on the vacuum gauges 36, 38, the positioning and movement of the platen 32 over a period of time could be predetermined to adjust the flow rate accordingly. Both approaches may be accomplished by configuring a controller, not shown, to control the movement of the object receiving mechanism 130 to adjust the throttling of the exhaust flow from the interior of the chamber 10 based on the position of the object receiving mechanism 130 or data from the vacuum gauges 36, 38. In this manner platen position can be adjusted to provide necessary conductance for the chamber to be evacuated in a suitable time frame without causing particle stirring within the chamber.

[00027] During the chamber evacuation valves 20 and 22 are in bypass mode so that steady gas conditions are achieved for precursor gas species A and B.

[00028] Once an appropriate reduced pressure is achieved, the movement mechanism 52 is moved downwards to create minimum conductance to the vacuum pump 18. The 3 way valve 20 is then switched to allow flow of vapor/gas species A to the chamber 10 to deposit a monatomic layer onto the substrate. During this process the chamber pressure will rise to around atmospheric pressure. The valve 20 is then switched to bypass and the movement mechanism 52 moves upward to allow evacuation of the chamber 10 to remove vapor/gas species A. After a reduced pressure is obtained, the movement mechanism 52 moves downward to provide the minimum conductance to the vacuum pump and valve 22 is switched to allow flow of vapor/gas species B to the chamber 10 to deposit a monatomic layer onto the substrate.

[00029] The above process is repeated to provide sequential deposition of a plurality of layers of A and B until the desired deposition thickness is achieved. Each species/layer can be deposited in a 1-2 second cycle time.

[00030] On completion of the deposition process isolation valve 48 is opened, valve 42 is closed and valve 35 is opened to allow the wafer vacuum hold down to be released. The gate valve 30 is then opened to allow the substrate to be removed from the chamber.

[00031] The process chamber 10 may be connected to a conventional vacuum cluster central handler or alternatively connected to an atmospheric robot handling system. This allows atomic layer deposition processes to be integrated to any configuration of wafer processing architecture.

[00032] An alternate embodiment including a purge gas system is shown in Figure 4. In between introduction of precursor gas A and precursor gas B to the process reactor, a purge gas, for example, nitrogen or argon, is introduced into the process reactor chamber 10.

Each of valve 20 and 22 are in bypass mode as the purge gas flows into process chamber 10 through valve 200. The purge gas flows through process reactor chamber 10 to the vacuum pump. Preferably, the purge gas is introduced into process reactor chamber 10 at a pressure of 5 standard (std) liters per minute for less than 5 seconds duration, more preferably 1 standard (std) liter per minute for less than 2 seconds duration. Unlike conventional systems, in which a full dose of purge gas is introduced into the process chamber at a pressure of 10 std liters per minute for 5 to 10 seconds, the purge process is substantially reduced. In this manner, the invention provides for fast cycle times.

[00033] An embodiment including a purge gas system wherein the precursor gases are metered using two way valves is shown in Figure 5. The two sets of two way valves 210 and 220 control the flow of precursor gas A and precursor gas B.

[00034] Although preferred embodiments are specifically illustrated and described herein above, it will be appreciated that many modifications and variations of the present invention are possible in light of the above teachings and within the preview of the appended claims without departing from the spirit and intended scope of the invention.